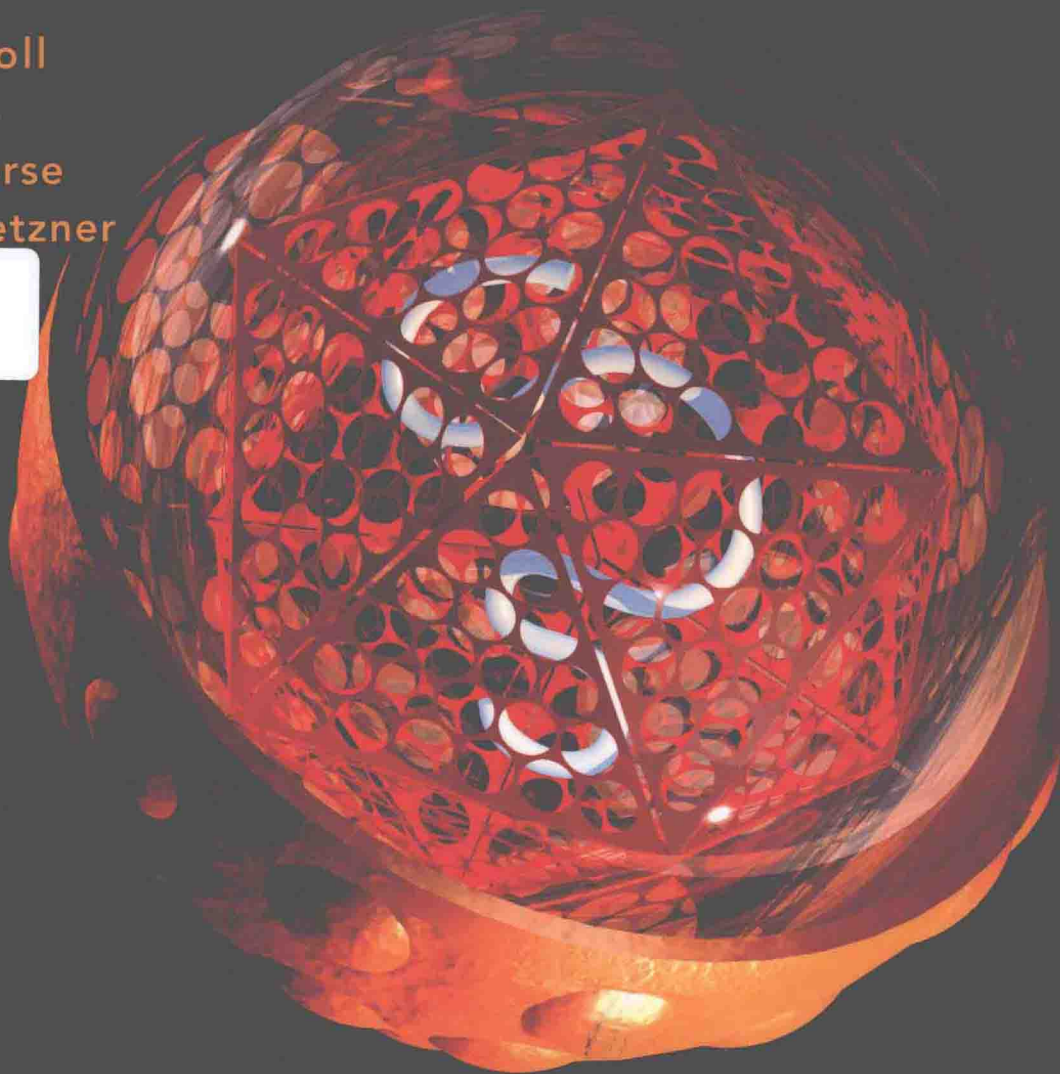
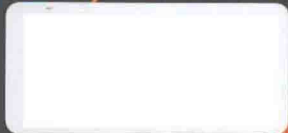


Geo. F. Brooks
Karen C. Carroll
Janet S. Butel
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Jawetz, Melnick & Adelberg's

MEDICAL MICROBIOLOGY

26th Edition

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Jawetz, Melnick, & Adelberg's Medical Microbiology

Twenty-Sixth Edition

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SELECTED MEDICALLY IMPORTANT MICROORGANISMS

I. BACTERIA

AEROBIC AND FACULTATIVE BACTERIA

GRAM-POSITIVE COCCI

Catalase-Positive

Staphylococcus aureus
Staphylococcus epidermidis
Staphylococcus intermedius
Staphylococcus lugdunensis
Staphylococcus saprophyticus
Staphylococcus species

Catalase-Negative

Aerococcus species
Enterococcus faecalis
Enterococcus faecium
Enterococcus species
Gemella species
Lactococcus species
Leuconostoc species
Pediococcus species
Streptococcus agalactiae
 (Group B)
Streptococcus canis
 (Group G)
Streptococcus gallolyticus
 (Group D, formerly
S. bovis)
Streptococcus infantarius
 (Group D, formerly
S. bovis)
Streptococcus pneumoniae
Streptococcus pyogenes
 (Group A)
 Viridans group
 streptococci
Streptococcus anginosus
Streptococcus constellatus
Streptococcus intermedius
Streptococcus mitis
Streptococcus mutans
Streptococcus salivarius
Streptococcus sanguis
Abiotrophia species
 (nutritionally variant
 streptococci)
Granulicatella species
 (nutritionally variant
 streptococci)

GRAM-NEGATIVE COCCI

Moraxella catarrhalis
Neisseria gonorrhoeae
Neisseria meningitidis
Neisseria species

GRAM-POSITIVE BACILLI

Arcanobacterium species
Bacillus anthracis
Bacillus cereus

Corynebacterium diphtheriae
Corynebacterium jeikeium
Corynebacterium species
Corynebacterium urealyticum
Erysipelothrix rhusiopathiae
Gardnerella vaginalis
Gordonia species
Listeria monocytogenes
Mycobacterium abscessus
Mycobacterium avium
Mycobacterium bovis
Mycobacterium chelonae
Mycobacterium fortuitum
Mycobacterium intracellulare
Mycobacterium kansasii
Mycobacterium leprae
Mycobacterium marinum
Mycobacterium tuberculosis
Mycobacterium species
Nocardia asteroides
Rhodococcus equi
Tropheryma whippeli
Tsukamurella species

GRAM-NEGATIVE BACILLI

Enterobacteriaceae

Citrobacter freundii
Citrobacter koseri
Citrobacter species
Cronobacter sakazakii
Edwardsiella tarda
Enterobacter aerogenes
Enterobacter cloacae
Escherichia coli
Escherichia species
Klebsiella oxytoca
Klebsiella granulomatis
Klebsiella pneumoniae
Klebsiella pneumoniae
 subspecies
 rhinocleromatis
Morganella morganii
Plesiomonas shigelloides
Proteus mirabilis
Proteus vulgaris
Providencia alcalifaciens
Providencia rettgeri
Providencia stuartii
Salmonella Choleraesuis
Salmonella Paratyphi A
Salmonella Paratyphi B
Salmonella Typhi
Salmonella species
Serratia liquefaciens
Serratia marcescens
Shigella boydii
Shigella dysenteriae

Shigella flexneri
Shigella sonnei
Yersinia enterocolitica
Yersinia pestis
Yersinia pseudotuberculosis

Nonenterobacteriaceae—

Fermentative Bacilli

Aeromonas caviae
Aeromonas hydrophila
Aeromonas species
Aeromonas veronii biovar sobria
Pasteurella multocida
Vibrio cholerae
Vibrio parahaemolyticus
Vibrio species
Vibrio vulnificus

Nonenterobacteriaceae—

Nonfermentative Bacilli

Acinetobacter species
Alcaligenes species
Brevundimonas species
Burkholderia cepacia
Burkholderia mallei
Burkholderia pseudomallei
Chryseobacterium species
Comamonas species
Eikenella corrodens
Moraxella species
Pseudomonas aeruginosa
Pseudomonas fluorescens
Pseudomonas species
Ralstonia pickettii
Roseomonas species
Shewanella putrefaciens
Sphingobacterium species
Sphingomonas species
Stenotrophomonas maltophilia

OTHER GRAM-NEGATIVE BACILLI AND COCCOBACILLI

Aggregatibacter (Actinobacillus) actinomycetemcomitans
Aggregatibacter (Haemophilus) aphrophilus
Arcobacter species
Bartonella bacilliformis
Bartonella henselae
Bartonella species
Bordetella bronchiseptica
Bordetella parapertussis
Bordetella pertussis
Bordetella species
Brucella melitensis
Brucella species

Campylobacter fetus
Campylobacter jejuni
Campylobacter species
Capnocytophaga species
Cardiobacterium hominis
Chlamydomphila pneumoniae
Chlamydomphila psittaci
Chlamydia trachomatis
Ehrlichia chaffeensis
Francisella tularensis
Haemophilus aegyptius
Haemophilus ducreyi
Haemophilus influenzae
Haemophilus parainfluenzae
Haemophilus species
Helicobacter pylori
Kingella kingae
Legionella micdadei
Legionella pneumophila
Legionella species
Orientia tsutsugamushi
Streptobacillus moniliformis

MYCOPLASMAS

Mycoplasma genitalium
Mycoplasma hominis
Mycoplasma pneumoniae
Mycoplasma species
Ureaplasma urealyticum

RICKETTSIA AND RELATED ORGANISMS

Anaplasma

Ehrlichia

Ehrlichia chaffeensis
Ehrlichia ewingii

Rickettsia

Rickettsia akari
Rickettsia conorii
Rickettsia mooseri
Rickettsia prowazekii
Rickettsia rickettsii

SPIRAL ORGANISMS

Borrelia burgdorferi
Borrelia recurrentis
Leptospira interrogans
Treponema pallidum

ANAEROBIC BACTERIA

GRAM-NEGATIVE BACILLI

Bacteroides fragilis group
Bacteroides ovatus
B. distasonis
B. thetaiotaomicron
B. vulgatus
Bacteroides species
Fusobacterium necrophorum
Fusobacterium nucleatum
Mobiluncus species

Preface

The twenty-sixth edition of *Jawetz, Melnick, & Adelberg's Medical Microbiology* remains true to the goals of the first edition published in 1954 "to provide a brief, accurate and up-to-date presentation of those aspects of medical microbiology that are of particular significance to the fields of clinical infections and chemotherapy." The 26th edition has included the following new features!

- Addition of concept checks after major sections within chapters.
- Chapter Summaries at the end of each chapter.
- Increased number of new and revised review questions.
- Full color photographs and photomicrographs of the previous edition.
- All chapters have been revised extensively consistent with the tremendous expansion of medical knowledge afforded by molecular mechanisms, advances in our understanding of microbial pathogenesis and the discovery of novel pathogens.

New also to this edition is Barbara Detrick, PhD, Professor in the Division of Clinical Immunology in the Department of Pathology at the Johns Hopkins University School of Medicine. Dr. Detrick's extensive expertise in clinical immunology, and

in particular the role of cytokines in health and disease, will add significantly to the current and future editions and we welcome her participation.

The authors hope that the changes to this edition will be helpful to the student of microbiology.

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November 2012

Contents

Preface xi

SECTION I

FUNDAMENTALS OF MICROBIOLOGY 1

Stephen A. Morse, PhD, and Timothy A. Meitzner, PhD*

1. The Science of Microbiology 1

- Introduction 1
- Biologic Principles Illustrated by Microbiology 1
- Viruses 2
- Prions 2
- Prokaryotes 3
- Protists 6
- Chapter Summary 8
- Review Questions 8

2. Cell Structure 11

- Optical Methods 11
- Eukaryotic Cell Structure 13
- Prokaryotic Cell Structure 15
- Staining 39
- Morphologic Changes During Growth 40
- Chapter Summary 40
- Review Questions 41

3. Classification of Bacteria 43

- Taxonomy—The Vocabulary of Medical Microbiology 43
- Criteria for Classification of Bacteria 44
- Classification Systems 45
- Description of the Major Categories and Groups of Bacteria 48
- Subtyping and Its Application 50
- Nucleic Acid–Based Taxonomy 51
- Nonculture Methods for the Identification of Pathogenic Microorganisms 53
- Objectives 53
- Review Questions 53

4. The Growth, Survival, and Death of Microorganisms 55

- Survival of Microorganisms in the Natural Environment 55

The Meaning of Growth 55

Exponential Growth 55

The Growth Curve 57

Maintenance of Cells in the Exponential Phase 58

Definition and Measurement of Death 58

Antimicrobial Agents 60

Objectives 65

Review Questions 65

5. Cultivation of Microorganisms 67

- Requirements for Growth 67
- Sources of Metabolic Energy 67
- Nutrition 68
- Environmental Factors Affecting Growth 69
- Cultivation Methods 72
- Chapter Summary 75
- Review Questions 76

6. Microbial Metabolism 77

- Role of Metabolism in Biosynthesis and Growth 77
- Focal Metabolites and Their Interconversion 77
- Assimilatory Pathways 80
- Biosynthetic Pathways 88
- Patterns of Microbial Energy-Yielding Metabolism 91
- Regulation of Metabolic Pathways 96
- Chapter Summary 98
- Review Questions 99

7. Microbial Genetics 101

- Organization of Genes 101
- Replication 106
- Transfer of DNA 107
- Mutation and Gene Rearrangement 111
- Gene Expression 111
- Genetic Engineering 115
- Characterization of Cloned DNA 118
- Site-Directed Mutagenesis 119
- Analysis With Cloned DNA: Hybridization Probes 119

Manipulation of Cloned DNA	120
Objectives	121
Objectives	121

SECTION II

IMMUNOLOGY 123

Barbara Detrick, PhD

8. Immunology	123
Overview	123
Innate Immunity	123
Adaptive Immunity	127
Complement	138
Cytokines	140
Hypersensitivity	141
Deficiencies of the Immune Response	142
Clinical Immunology Laboratory (Diagnostic Testing)	143
Chapter Summary	145
Review Questions	147

SECTION III

BACTERIOLOGY 149

Karen C. Carroll, MD

9. Pathogenesis of Bacterial Infection	149
Identifying Bacteria That Cause Disease	150
Transmission of Infection	151
The Infectious Process	152
Genomics and Bacterial Pathogenicity	152
Regulation of Bacterial Virulence Factors	153
Bacterial Virulence Factors	154
Chapter Summary	161
Review Questions	162
10. Normal Human Microbiota	165
Human Microbiome Project	165
Role of the Resident Microbiota	165
Normal Microbiota of the Skin	167
Normal Microbiota of the Mouth and Upper Respiratory Tract	167
Normal Microbiota of the Urethra	172
Normal Microbiota of the Vagina	172
Normal Microbiota of the Conjunctiva	172
Chapter Summary	172
Review Questions	173
11. Spore-Forming Gram-Positive Bacilli: <i>Bacillus</i> and <i>Clostridium</i> Species	175
<i>Bacillus</i> Species	175
<i>Bacillus anthracis</i>	175

<i>Bacillus cereus</i>	178
<i>Clostridium</i> Species	178
<i>Clostridium botulinum</i>	179
<i>Clostridium tetani</i>	180
Clostridia That Produce Invasive Infections	181
<i>Clostridium difficile</i> and Diarrheal Disease	183
Review Questions	183

12. Aerobic Non-Spore-Forming Gram-Positive Bacilli: <i>Corynebacterium</i>, <i>Listeria</i>, <i>Erysipelothrix</i>, <i>Actinomycetes</i>, and Related Pathogens	187
<i>Corynebacterium diphtheriae</i>	188
Other Coryneform Bacteria	191
<i>Listeria monocytogenes</i>	192
<i>Erysipelothrix rhusiopathiae</i>	193
<i>Actinomycetes</i>	194
Nocardiosis	194
Actinomycetoma	195
Review Questions	195
13. The Staphylococci	199
Chapter Summary	205
Review Questions	206
14. The Streptococci, Enterococci, and Related Genera	209
Classification of Streptococci	209
Streptococci of Particular Medical Interest	211
<i>Streptococcus pyogenes</i>	211
<i>Streptococcus agalactiae</i>	216
Groups C and G	217
Group D Streptococci	217
<i>Streptococcus anginosus</i> Group	217
Group N Streptococci	217
Groups E, F, G, H, and K–U Streptococci	217
Viridans Streptococci	218
Nutritionally Variant Streptococci	218
Peptostreptococcus and Related Genera	218
<i>Streptococcus pneumoniae</i>	218
Enterococci	222
Other Catalase-Negative Gram-Positive Cocci	224
Review Questions	225
15. Enteric Gram-Negative Rods (<i>Enterobacteriaceae</i>)	229
Classification	229
Diseases Caused by <i>Enterobacteriaceae</i> Other Than <i>Salmonella</i> and <i>Shigella</i>	233
The Shigellae	236
The <i>Salmonella</i> -Arizona Group	238
Chapter Summary	241
Review Questions	241

16. **Pseudomonads, Acinetobacters, and Uncommon Gram-Negative Bacteria** 245
 - The Pseudomonad Group** 245
 - Pseudomonas aeruginosa* 245
 - Burkholderia pseudomallei* 248
 - Burkholderia mallei* 248
 - Burkholderia cepacia* Complex and *Burkholderia Gladioli* 248
 - Stenotrophomonas maltophilia* 249
 - Acinetobacter** 249
 - Other Pseudomonads 249
 - Uncommon Gram-Negative Bacteria** 250
 - Aggregatibacter* 250
 - Achromobacter* and *Alcaligenes* 250
 - Ochrobactrum* 250
 - Capnocytophaga* 250
 - Cardiobacterium* 250
 - Chromobacteria* 250
 - Eikenella corrodens* 251
 - Chryseobacterium* 251
 - Kingella* 251
 - Moraxella* 251
 - Chapter Summary 251
 - Review Questions 251
17. **Vibrios, Campylobacters, Helicobacter, and Associated Bacteria** 255
 - The Vibrios** 255
 - Vibrio Cholerae* 255
 - Vibrio Parahaemolyticus* and Other Vibrios 258
 - Aeromonas** 259
 - Plesiomonas* 259
 - Campylobacter** 259
 - Campylobacter Jejuni* and *Campylobacter Coli* 259
 - Campylobacter fetus* 261
 - Other Campylobacters 261
 - Helicobacter Pylori* 261
 - Review Questions 263
18. **Haemophilus, Bordetella, Brucella, and Francisella** 265
 - The Haemophilus Species** 265
 - Haemophilus influenzae* 265
 - Haemophilus aegyptius* 267
 - Aggregatibacter aphrophilus* 268
 - Haemophilus ducreyi* 268
 - Other *Haemophilus* Species 268
 - The Bordetellae** 268
 - Bordetella pertussis* 268
 - Bordetella parapertussis* 270
 - Bordetella bronchiseptica* 270
 - The Brucellae** 271
 - Francisella Tularensis* and *Tularemia* 273
 - Review Questions 275
19. **Yersinia and Pasteurella** 279
 - Yersinia pestis* and Plague 279
 - Yersinia enterocolitica* and *Yersinia pseudotuberculosis* 281
 - Pasteurella* 282
 - Review Questions 282
20. **The Neisseriae** 285
 - Neisseria gonorrhoeae* 285
 - Neisseria meningitidis* 291
 - Other *Neisseriae* 292
 - Chapter Summary 293
 - Review Questions 293
21. **Infections Caused by Anaerobic Bacteria** 295
 - Physiology and Growth Conditions for Anaerobes** 295
 - Anaerobic Bacteria Found in Human Infections 296
 - Bacteria That Cause Vaginosis** 297
 - Gardnerella vaginalis* 297
 - Mobiluncus* Species 297
 - Pathogenesis of Anaerobic Infections 300
 - Immunity in Anaerobic Infections 300
 - The Polymicrobial Nature of Anaerobic Infections 300
 - Diagnosis of Anaerobic Infections 301
 - Treatment of Anaerobic Infections 301
 - Chapter Summary 301
 - Review Questions 302
22. **Legionellae, Bartonella, and Unusual Bacterial Pathogens** 305
 - Legionella pneumophila* and Other Legionellae 305
 - Bartonella* 308
 - Streptobacillus moniliformis* 310
 - Whipple Disease 310
 - Review Questions 310
23. **Mycobacteria** 313
 - Mycobacterium tuberculosis* 313
 - Other Mycobacteria 321
 - Mycobacterium leprae* 323
 - Review Questions 324
24. **Spirochetes and Other Spiral Microorganisms** 327
 - Treponema** 327
 - Treponema pallidum* and Syphilis 327
 - Diseases Related To Syphilis 331
 - Borrelia** 331
 - Borrelia* Species and Relapsing Fever 331
 - Borrelia burgdorferi* and Lyme Disease 333
 - Leptospira and Leptospirosis** 335
 - Other Spirochetal Diseases** 337
 - Spirillum minor* (*Spirillum morsus muris*) 337

- Spirochetes of the Normal Mouth and Mucous Membranes 337
Review Questions 338
- 25. Mycoplasmas and Cell Wall-Defective Bacteria 341**
Mycoplasmas 341
Mycoplasma pneumoniae and Atypical Pneumonias 343
Mycoplasma hominis 344
Ureaplasma urealyticum 345
Mycoplasma genitalium 345
Cell Wall-Defective Bacteria 345
Chapter Summary 345
Review Questions 345
- 26. Rickettsia and Related Genera 349**
General 349
Rickettsia and *Orientia* 349
Ehrlichia and *Anaplasma* 353
Coxiella Burnetii 354
Review Questions 356
- 27. Chlamydia Spp. 359**
***Chlamydia Trachomatis* Ocular, Genital, and Respiratory Infections 362**
Trachoma 362
Chlamydia trachomatis Genital Infections and Inclusion Conjunctivitis 363
***Chlamydia Trachomatis* And Neonatal Pneumonia 364**
Lymphogranuloma Venereum 364
Chlamydia pneumoniae and Respiratory Infections 365
Chlamydia psittaci and Psittacosis 366
Chapter Summary 368
Review Questions 368
- 28. Antimicrobial Chemotherapy 371**
Mechanisms Of Action Of Antimicrobial Drugs 371
Selective Toxicity 371
Inhibition of Cell Wall Synthesis 371
Inhibition of Cell Membrane Function 373
Inhibition of Protein Synthesis 373
Inhibition of Nucleic Acid Synthesis 375
Resistance To Antimicrobial Drugs 375
Origin of Drug Resistance 376
Cross-Resistance 376
Limitation of Drug Resistance 376
Clinical Implications of Drug Resistance 377
Factors Affecting Antimicrobial Activity 378
Antimicrobial Activity In Vitro 378
Measurement of Antimicrobial Activity 379
Drug-Pathogen Relationships 379
- Antimicrobial Activity In Vivo 379**
Host-Pathogen Relationships 380
Clinical Use Of Antibiotics 381
Selection of Antibiotics 381
Dangers of Indiscriminate Use 381
Antimicrobial Drugs Used in Combination 382
Antimicrobial Chemoprophylaxis 383
Antimicrobial Drugs For Systemic Administration 384
Penicillins 384
Cephalosporins 390
Other β -Lactam Drugs 393
Tetracyclines 394
Glycylcyclines 394
Chloramphenicol 395
Erythromycins 395
Clindamycin and Lincomycin 396
Glycopeptides and Lipopeptides 396
Streptogramins 397
Oxazolidinones 397
Bacitracin 397
Polymyxins 397
Aminoglycosides 398
Quinolones 399
Sulfonamides and Trimethoprim 401
Other Drugs With Specialized Uses 401
Drugs Used Primarily To Treat Mycobacterial Infections 402
Review Questions 403
-
- SECTION IV**
VIROLOGY 407
-
- Jane Butel, PhD*
- 29. General Properties of Viruses 407**
Terms and Definitions in Virology 407
Evolutionary Origin of Viruses 408
Classification of Viruses 408
Principles of Virus Structure 414
Chemical Composition of Viruses 415
Cultivation and Assay of Viruses 416
Purification and Identification of Viruses 418
Laboratory Safety 419
Reaction To Physical and Chemical Agents 419
Replication of Viruses: An Overview 420
Genetics of Animal Viruses 425
Natural History (Ecology) and Modes of Transmission of Viruses 427
Chapter Summary 428
Review Questions 429

- 30. Pathogenesis and Control of Viral Diseases 431**
 - Principles of Viral Diseases 431
 - Pathogenesis of Viral Diseases 431
 - Prevention and Treatment of Viral Infections 441
 - Chapter Summary 449
 - Review Questions 449
- 31. Parvoviruses 451**
 - Properties of Parvoviruses 451
 - Parvovirus Infections in Humans 452
 - Chapter Summary 455
 - Review Questions 455
- 32. Adenoviruses 457**
 - Properties of Adenoviruses 457
 - Adenovirus Infections in Humans 461
 - Chapter Summary 464
 - Review Questions 464
- 33. Herpesviruses 467**
 - Properties of Herpesviruses 467
 - Herpesvirus Infections in Humans 471**
 - Herpes Simplex Viruses 471
 - Varicella-Zoster Virus 476
 - Cytomegalovirus 480
 - Epstein-Barr Virus 484
 - Human Herpesvirus 6 487
 - Human Herpesvirus 7 487
 - Human Herpesvirus 8 488
 - B Virus 488
 - Chapter Summary 489
 - Review Questions 489
- 34. Poxviruses 493**
 - Properties of Poxviruses 493
 - Poxvirus Infections in Humans: Vaccinia and Variola 496
 - Monkeypox Infections 501
 - Cowpox Infections 501
 - Buffalopox Infections 501
 - Orf Virus Infections 501
 - Molluscum Contagiosum 501
 - Tanapox and Yaba Monkey Tumor Poxvirus Infections 503
 - Chapter Summary 504
 - Review Questions 504
- 35. Hepatitis Viruses 507**
 - Properties of Hepatitis Viruses 507
 - Hepatitis Virus Infections in Humans 512
 - Chapter Summary 524
 - Review Questions 524
- 36. Picornaviruses (Enterovirus and Rhinovirus Groups) 527**
 - Properties of Picornaviruses 527
 - Enterovirus Group 531**
 - Polioviruses 531
 - Coxsackieviruses 533
 - Other Enteroviruses 536
 - Enteroviruses in the Environment 537
 - Rhinoviruses 538
 - Parechovirus Group 539**
 - Foot-And-Mouth Disease (Aphthovirus Of Cattle) 539**
 - Chapter Summary 540
 - Review Questions 540
- 37. Reoviruses, Rotaviruses, and Caliciviruses 543**
 - Reoviruses and Rotaviruses 543**
 - Rotaviruses 544
 - Reoviruses 548
 - Caliciviruses 548**
 - Orbiviruses and Coltiviruses 548
 - Astroviruses 551**
 - Chapter Summary 551
 - Review Questions 551
- 38. Arthropod-Borne and Rodent-Borne Viral Diseases 553**
 - Human Arbovirus Infections 553**
 - Togavirus and Flavivirus Encephalitis 555
 - Yellow Fever 562
 - Dengue 564
 - Bunyavirus Encephalitis 566
 - Sandfly Fever 566
 - Rift Valley Fever 566
 - Colorado Tick Fever 567
 - Rodent-Borne Hemorrhagic Fevers 567**
 - Bunyavirus Diseases 567
 - Arenavirus Diseases 569
 - Filovirus Diseases 571
 - Chapter Summary 573
 - Review Questions 573
- 39. Orthomyxoviruses (Influenza Viruses) 577**
 - Properties of Orthomyxoviruses 577
 - Influenza Virus Infections in Humans 583
 - Chapter Summary 588
 - Review Questions 589
- 40. Paramyxoviruses and Rubella Virus 591**
 - Properties of Paramyxoviruses 591
 - Parainfluenza Virus Infections 594
 - Respiratory Syncytial Virus Infections 598
 - Human Metapneumovirus Infections 600
 - Mumps Virus Infections 601

- Measles (Rubeola) Virus Infections 603
 Hendra Virus and Nipah Virus Infections 606
Rubella (German Measles) Virus Infections 607
 Postnatal Rubella 607
 Congenital Rubella Syndrome 609
 Chapter Summary 609
 Review Questions 510
- 41. Coronaviruses 613**
 Properties of Coronaviruses 613
 Coronavirus Infections in Humans 615
 Chapter Summary 617
 Review Questions 617
- 42. Rabies, Slow Virus Infections, and Prion Diseases 619**
 Rabies 619
 Borna Disease 626
 Slow Virus Infections and Prion Diseases 626
 Chapter Summary 629
 Review Questions 629
- 43. Human Cancer Viruses 633**
 General Features of Viral Carcinogenesis 633
 Retroviruses 635
 Cellular Oncogenes 641
 Tumor Suppressor Genes 642
DNA Tumor Viruses 642
 Polyomaviruses 642
 Papillomaviruses 644
 Adenoviruses 647
 Herpesviruses 648
 Poxviruses 648
 Hepatitis B Virus and Hepatitis C Virus 648
How to Prove That a Virus Causes Human Cancer 649
 Chapter Summary 649
 Review Questions 649
- 44. AIDS and Lentiviruses 653**
 Properties of Lentiviruses 653
 HIV Infections in Humans 657
 Chapter Summary 667
 Review Questions 667

SECTION V

MYCOLOGY 671

Thomas G. Mitchell, PhD

- 45. Medical Mycology 671**
 General Properties and Classification of Fungi 672
 Growth and Isolation of Fungi 676

- Superficial Mycoses 676
 Cutaneous Mycoses 677
 Key Concepts: Superficial and Cutaneous Mycoses 681
 Subcutaneous Mycoses 681
 Sporotrichosis 681
 Chromoblastomycosis 682
 Phaeohyphomycosis 684
 Mycetoma 684
 Key Concepts: Subcutaneous Mycoses 685
 Endemic Mycoses 685
 Coccidioidomycosis 686
 Histoplasmosis 689
 Blastomycosis 692
 Paracoccidioidomycosis 693
 Key Concepts: Endemic Mycoses 694
 Opportunistic Mycoses 694
 Candidiasis 694
 Cryptococcosis 697
 Aspergillosis 699
 Mucormycosis 701
Pneumocystis Pneumonia 702
 Penicilliosis 702
 Other Opportunistic Mycoses 702
 Key Concepts: Opportunistic Mycoses 703
 Antifungal Prophylaxis 703
 Hypersensitivity to Fungi 703
 Mycotoxins 704
 Antifungal Chemotherapy 704
 Topical Antifungal Agents 709
 Key Concepts: Antifungal Chemotherapy 710
 Review Questions 710

SECTION VI

PARASITOLOGY 715

Judy A. Sakanari, PhD, and
 James H. McKerrow, MD, PhD

- 46. Medical Parasitology 715**
Classification of Parasites 715
Intestinal Protozoan Infections 719
Giardia lamblia (Intestinal Flagellate) 719
 Key Concepts: Parasitic Protozoa 719
Entamoeba histolytica (Intestinal and Tissue Ameba) 720
 Other Intestinal Amebae 722
Cryptosporidium (Intestinal Sporozoa) 722
Cyclospora (Intestinal Sporozoa) 723
Sexually Transmitted Protozoan Infection 723

<i>Trichomonas vaginalis</i> (Genitourinary Flagellate)	723
Blood and Tissue Protozoan Infections	723
Blood Flagellates	723
<i>Trypanosoma brucei rhodesiense</i> and <i>T b gambiense</i> (Blood Flagellates)	724
<i>Trypanosoma cruzi</i> (Blood Flagellate)	725
<i>Leishmania</i> Species (Blood Flagellates)	725
<i>Entamoeba histolytica</i> (Tissue Ameba)—See Intestinal Protozoan Infections Section	727
<i>Naegleria fowleri</i> , <i>Acanthamoeba castellanii</i> , and <i>Balamuthia mandrillaris</i> (Free-Living Amebae)	727
<i>Plasmodium</i> Species (Blood Sporozoa)	727
<i>Babesia microti</i> (Blood Sporozoa)	731
<i>Toxoplasma gondii</i> (Tissue Sporozoa)	732
Microsporidia	733
Intestinal Helminthic Infections	733
Key Concepts: Parasitic Helminths	733
<i>Enterobius vermicularis</i> (Pinworm—Intestinal Nematode)	734
<i>Trichuris trichiura</i> (Whipworm—Intestinal Nematode)	734
<i>Ascaris lumbricoides</i> (Human Roundworm—Intestinal Nematode)	738
<i>Ancylostoma duodenale</i> and <i>Necator americanus</i> (Human Hookworms—Intestinal Nematode)	739
<i>Strongyloides stercoralis</i> (Human Threadworm—Intestinal and Tissue Nematode)	740
<i>Trichinella spiralis</i> (Intestinal And Tissue Nematode)	741
<i>Fasciolopsis buski</i> (Giant Intestinal Fluke—Intestinal Trematode)	741
<i>Taenia saginata</i> (Beef Tapeworm—Intestinal Cestode) and <i>Taenia Solium</i> (Pork Tapeworm—Intestinal and Tissue Cestode)	741
<i>Diphyllobothrium latum</i> (Broad Fish Tapeworm—Intestinal Cestode)	742
<i>Hymenolepis nana</i> (Dwarf Tapeworm—Intestinal Cestode)	742
<i>Dipylidium caninum</i> (Dog Tapeworm—Intestinal Cestode)	743
<i>Wuchereria bancrofti</i> and <i>Brugia Malayi</i> (Lymphatic Filariasis—Tissue Nematodes)	743
Blood and Tissue Helminthic Infections	743
<i>Onchocerca volvulus</i> (River Blindness—Tissue Nematode)	743
<i>Dracunculus medinensis</i> (Guinea Worm—Tissue Nematode)	744
Larva Migrans (Zoonotic Larval Nematode Infections)	745

<i>Clonorchis sinensis</i> (Chinese Liver Fluke), <i>Fasciola hepatica</i> (Sheep Liver Fluke), and <i>Paragonimus westermani</i> (Lung Fluke)—Tissue Trematodes	745
<i>Schistosoma mansoni</i> , <i>S japonicum</i> , and <i>S haematobium</i> (Blood Flukes)	746
Tissue Cestode Infections (Caused by the Larval Stages)	746
<i>Taenia solium</i> —Cysticercosis/Neurocysticercosis	746
<i>Echinococcus granulosus</i> (Hydatid Cyst)	746
Review Questions	748

SECTION VII

DIAGNOSTIC MEDICAL MICROBIOLOGY AND CLINICAL CORRELATION 753

Karen C. Carroll, MD

47. Principles of Diagnostic Medical Microbiology	753
Communication Between Physician and Laboratory	753
Diagnosis of Bacterial and Fungal Infections	754
The Importance of Normal Bacterial and Fungal Microbiota	765
Laboratory Aids in the Selection of Antimicrobial Therapy	766
Diagnosis of Infection by Anatomic Site	767
Anaerobic Infections	773
Diagnosis of Chlamydial Infections	773
Diagnosis of Viral Infections	775
Review Questions	783
48. Cases and Clinical Correlations	785
Central Nervous System	785
Respiratory	789
Heart	793
Abdomen	795
Urinary Tract	800
Bone and Soft Tissue	802
Sexually Transmitted Diseases	803
<i>Mycobacterium Tuberculosis</i> Infections	806
HIV-1 and Aids	809
Infections in Transplant Patients	813
Biologic Warfare and Bioterrorism	817

SECTION I FUNDAMENTALS OF MICROBIOLOGY

CHAPTER

1

The Science of Microbiology

INTRODUCTION

Microbiology is the study of microorganisms, a large and diverse group of microscopic organisms that exist as single cells or cell clusters; it also includes viruses, which are microscopic but not cellular. Microorganisms have a tremendous impact on all life and the physical and chemical makeup of our planet. They are responsible for cycling the chemical elements essential for life, including carbon, nitrogen, sulfur, hydrogen, and oxygen; more photosynthesis is carried out by microorganisms than by green plants. Furthermore, there are 100 million times as many bacteria in the oceans (13×10^{28}) as there are stars in the known universe. The rate of viral infections in the oceans is about 1×10^{23} infections per second, and these infections remove 20–40% of all bacterial cells each day. It has been estimated that 5×10^{30} microbial cells exist on earth; excluding cellulose, these cells constitute about 90% of the biomass of the entire biosphere. Humans also have an intimate relationship with microorganisms; more than 90% of the cells in our bodies are microbes. The bacteria present in the average human gut weigh about 1 kg, and a human adult will excrete his or her own weight in fecal bacteria each year. The number of genes contained within this gut flora outnumber that contained within our genome 150-fold, and even in our own genome, 8% of the DNA is derived from remnants of viral genomes.

BIOLOGIC PRINCIPLES ILLUSTRATED BY MICROBIOLOGY

Nowhere is **biologic diversity** demonstrated more dramatically than by microorganisms, creatures that are not directly

visible to the unaided eye. In form and function, be it biochemical property or genetic mechanism, analysis of microorganisms takes us to the limits of biologic understanding. Thus, the need for **originality**—one test of the merit of a scientific **hypothesis**—can be fully met in microbiology. A useful hypothesis should provide a basis for **generalization**, and microbial diversity provides an arena in which this challenge is ever present.

Prediction, the practical outgrowth of science, is a product created by a blend of technique and theory. **Biochemistry**, **molecular biology**, and **genetics** provide the tools required for analysis of microorganisms. **Microbiology**, in turn, extends the horizons of these scientific disciplines. A biologist might describe such an exchange as **mutualism**, that is, one that benefits all of the contributing parties. Lichens are an example of microbial mutualism. Lichens consist of a fungus and phototropic partner, either an alga (a eukaryote) or a cyanobacterium (a prokaryote). The phototropic component is the primary producer, and the fungus provides the phototroph with an anchor and protection from the elements. In biology, mutualism is called **symbiosis**, a continuing association of different organisms. If the exchange operates primarily to the benefit of one party, the association is described as **parasitism**, a relationship in which a **host** provides the primary benefit to the parasite. Isolation and characterization of a parasite—such as a pathogenic bacterium or virus—often require effective mimicry in the laboratory of the growth environment provided by host cells. This demand sometimes represents a major challenge to investigators.

The terms *mutualism*, *symbiosis*, and *parasitism* relate to the science of **ecology**, and the principles of environmental biology are implicit in microbiology. Microorganisms are

the products of **evolution**, the biologic consequence of **natural selection** operating on a vast array of genetically diverse organisms. It is useful to keep the complexity of natural history in mind before generalizing about microorganisms, the most heterogeneous subset of all living creatures.

A major biologic division separates the eukaryotes, organisms containing a membrane-bound nucleus, from prokaryotes, organisms in which DNA is not physically separated from the cytoplasm. As described in this chapter and in Chapter 2, further major distinctions can be made between eukaryotes and prokaryotes. Eukaryotes, for example, are distinguished by their relatively large size and by the presence of specialized membrane-bound organelles such as mitochondria.

As described more fully later in this chapter, eukaryotic microorganisms—or, phylogenetically speaking, the Eukarya—are unified by their distinct cell structure and phylogenetic history. Among the groups of eukaryotic microorganisms are the **algae**, the **protozoa**, the **fungi**, and the **slime molds**.

VIRUSES

The unique properties of viruses set them apart from living creatures. Viruses lack many of the attributes of cells, including the ability to replicate. Only when it infects a cell does a virus acquire the key attribute of a living system—reproduction. Viruses are known to infect all cells, including microbial cells. Recently, viruses called **virophages** have been discovered that infect other viruses. Host–virus interactions tend to be highly specific, and the biologic range of viruses mirrors the diversity of potential host cells. Further diversity of viruses is exhibited by their broad array of strategies for replication and survival.

Viral particles are generally small (eg, adenovirus is 90 nm) and consist of a nucleic acid molecule, either DNA or RNA, enclosed in a protein coat, or capsid (sometimes itself enclosed by an envelope of lipids, proteins, and carbohydrates). Proteins—frequently glycoproteins—in the capsid determine the specificity of interaction of a virus with its host cell. The capsid protects the nucleic acid and facilitates attachment and penetration of the host cell by the virus. Inside the cell, viral nucleic acid redirects the host's enzymatic machinery to functions associated with replication of the virus. In some cases, genetic information from the virus can be incorporated as DNA into a host chromosome. In other instances, the viral genetic information can serve as a basis for cellular manufacture and release of copies of the virus. This process calls for replication of the viral nucleic acid and production of specific viral proteins. **Maturation** consists of assembling newly synthesized nucleic acid and protein subunits into mature viral particles, which are then liberated into the extracellular environment. Some very small viruses require the assistance of another virus in the host cell for their duplication. The delta agent, also known as hepatitis D virus, is too small to code for even a single capsid protein and needs help

from hepatitis B virus for transmission. Viruses are known to infect a wide variety of plant and animal hosts as well as protists, fungi, and bacteria. However, most viruses are able to infect specific types of cells of only one host species.

Some viruses are large and complex. For example, Mimivirus, a DNA virus infecting *Acanthamoeba*, a free-living soil amoeba, has a diameter of 400–500 nm and a genome that encodes 979 proteins, including the first four aminoacyl tRNA synthetases ever found outside of cellular organisms and enzymes for polysaccharide biosynthesis. An even larger marine virus has recently been discovered (Megavirus); its genome (1,259,197-bp) encodes 1120 putative proteins and is larger than that of some bacteria (Table 7-1). Because of their large size, these viruses resemble bacteria when observed in stained preparations by light microscopy; however, they do not undergo cell division or contain ribosomes.

A number of transmissible plant diseases are caused by **viroids**—small, single-stranded, covalently closed circular RNA molecules existing as highly base-paired rodlike structures. They range in size from 246 to 375 nucleotides in length. The extracellular form of the viroid is naked RNA—there is no capsid of any kind. The RNA molecule contains no protein-encoding genes, and the viroid is therefore totally dependent on host functions for its replication. Viroid RNA is replicated by the DNA-dependent RNA polymerase of the plant host; preemption of this enzyme may contribute to viroid pathogenicity.

The RNAs of viroids have been shown to contain inverted repeated base sequences at their 3' and 5' ends, a characteristic of transposable elements (see Chapter 7) and retroviruses. Thus, it is likely that they have evolved from transposable elements or retroviruses by the deletion of internal sequences.

The general properties of animal viruses pathogenic for humans are described in Chapter 29. Bacterial viruses are described in Chapter 7.

PRIONS

A number of remarkable discoveries in the past 3 decades have led to the molecular and genetic characterization of the transmissible agent causing **scrapie**, a degenerative central nervous system disease of sheep. Studies have identified a scrapie-specific protein in preparations from scrapie-infected brains of sheep that is capable of reproducing the symptoms of scrapie in previously uninfected sheep (Figure 1-1). Attempts to identify additional components, such as nucleic acid, have been unsuccessful. To distinguish this agent from viruses and viroids, the term **prion** was introduced to emphasize its proteinaceous and infectious nature. The cellular form of the prion protein (PrP^c) is encoded by the host's chromosomal DNA. PrP^c is a sialoglycoprotein with a molecular mass of 33,000–35,000 daltons and a high content of α -helical secondary structure that is sensitive to proteases and soluble in detergent. PrP^c is expressed on the surface of neurons via a glycosylphosphatidyl inositol anchor in both infected and



FIGURE 1-1 Prion. Prions isolated from the brain of a scrapie-infected hamster. This neurodegenerative disease is caused by a prion. (Reproduced with permission from Stanley B. Prusiner.)

uninfected brains. A conformational change occurs in the prion protein, changing it from its normal or cellular form PrP^c to the disease-causing conformation, PrP^{Sc} (Figure 1-2). When PrP^{Sc} is present in an individual (owing to spontaneous conformational conversion or to infection), it is capable of recruiting PrP^c and converting it to the disease form. Thus, prions replicate using the PrP^c substrate that is present in the host.

There are additional prion diseases of importance (Table 1-1 and Chapter 42). Kuru, Creutzfeldt-Jakob disease (CJD), Gerstmann-Sträussler-Scheinker disease, and fatal familial insomnia affect humans. Bovine spongiform encephalopathy, which is thought to result from the ingestion of feeds and bone meal prepared from rendered sheep offal, has been responsible for the deaths of more than 184,000 cattle in Great Britain since its discovery in 1985. A new variant of CJD (vCJD) has been associated with human ingestion of prion-infected beef in the United Kingdom and France. A common feature of all of these diseases is the conversion of a host-encoded sialoglycoprotein to a protease-resistant form as a consequence of infection.

Human prion diseases are unique in that they manifest as sporadic, genetic, and infectious diseases. The study of prion biology is an important emerging area of biomedical investigation, and much remains to be learned.

The distinguishing features of the nonliving members of the microbial world are given in Table 1-2.

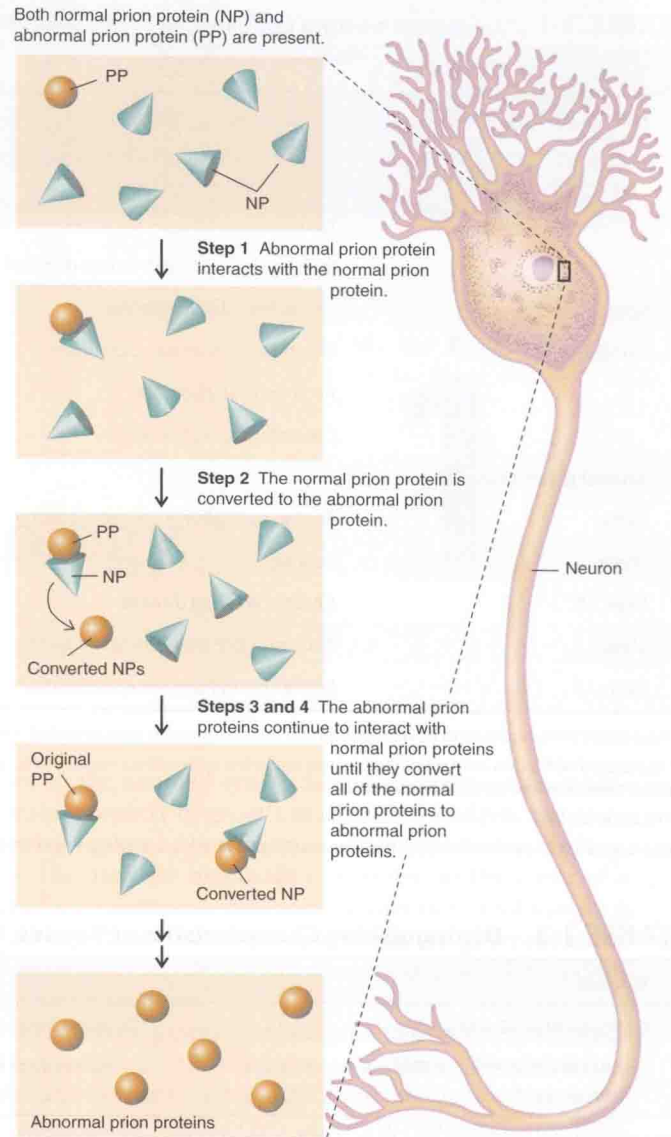


FIGURE 1-2 Proposed mechanism by which prions replicate. The normal and abnormal prion proteins differ in their tertiary structure. (Reproduced with permission from Nester EW, Anderson DG, Roberts CE, Nester MT (editors): *Microbiology: A Human Perspective*, 6th ed. McGraw-Hill, 2009, p. 342.)

PROKARYOTES

The primary distinguishing characteristics of the prokaryotes are their relatively small size, usually on the order of $1\ \mu\text{m}$ in diameter, and the absence of a nuclear membrane. The DNA of almost all bacteria is a circle with a length of about $1\ \text{mm}$; this is the prokaryotic chromosome. Most prokaryotes have only a single chromosome. The chromosomal DNA must be folded more than 1000-fold just to fit within the prokaryotic cell membrane. Substantial evidence suggests that the folding may be orderly and may bring specified regions of the DNA